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IR Field Measurements From the FISTA Aircraft; Calibration, Data Reduction, and Development of IR Signature Models

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13. ABSTRACT *(Maximum 200 words)*

This report summarizes the work performed under contract F19628-93-C-0183 from October 1993 to December 1998. All of the field measurements performed on the ground and in aircraft are summarized, with types of data and targets described. Data sets reduced and analyzed under this contract are listed. Databasing support of infrared data is presented, along with a list of aircraft target databases assembled and delivered. Aircraft infrared signature modeling work and support is also listed. Hardware and instrument development tasks accomplished are shown.

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1 Overview

The final report summarizes the work that Stewart Radiance Laboratory (SRL), of the Space Dynamics Laboratory (SDL) in the Utah State University Research Foundation, performed for the Air Force Research Laboratory (AFRL) Space Vehicles Directorate, Battlespace Environment (AFRL/VSBC). The period of performance was October 1993 to December 1998.

The statement of work (SOW) contained the following items:

SOW 1.0 - This task covers the selection of FISTA aircraft infrared data (data reduction), its conversion into absolute units (calibration), and subsequent analysis.

SOW 1.1 - IR Data Selection. This item covers the selection and initial reduction of data collected on FISTA flight missions.

SOW 1.2 - IR Data Calibration and Analysis. This item included data calibration, corrections, and analysis, as well as the use of infrared paint reflectance data.

SOW 1.2.1 - Data calibration steps

SOW 1.2.2 - IR Data Corrections and Analysis

SOW 1.2.3 - Obtain and Use Infrared Paint Data

SOW 1.3 - IR Signature Models. This item covers the use, validation, and application of existing models to the description and prediction of the infrared emissions of aircraft, rocket, and ground targets.

SOW 1.3.1 - Study target signatures using models

SOW 1.3.2 - Study backgrounds using models

SOW 1.3.3 - Atmospheric corrections to data

SOW 1.3.4 - Model useage for end customers

SOW 1.3.5 - Model Validation Work

SOW 1.4 - Instrumentation Development and Operation. This item covers the development and operation of infrared sensors and flight hardware in support of the FISTA aircraft program.

SOW 1.5 - Support Operational Commands. This item applies to measurement and analysis support for the requirements of Air Force operational commands.

SOW 2 This item directs SRL to provide 4 crewmembers for flights on the FISTA aircraft and to support aircraft field deployments.

2 Field Deployments (SOW 2.0)

Nine separate field deployments were supported under this contract effort. The flight measurements were part of item 2.0 of the SOW. The ground measurements occurred under SOW item 1.5. Each deployment is summarized in the following sections.

2.1 FISTA II Flight Checkout (May 1995)

After the aircraft class II modification to support FISTA instrumentation was completed in the spring of 1995, the 4950th Test Wing conducted several checkout flights at Wright-Patterson AFB in Ohio to verify that all systems were working properly. On one of these flights, AFRL and its contractors, including SRL, installed a suite of sensors, and did a short (3 hour) test flight in which sensors and recording systems were checked out. To provide some targets of opportunity, a rendezvous with Ohio Air National Guard F-16's was arranged. The FISTA aircraft refueled these aircraft in flight and collected a small body of data on them, solely for the purpose of verifying that systems were operational. The flight was a success and only minor problems, which were subsequently fixed, were discovered during this test.

2.2 Joint Stars and Countermeasure Data (Sept/Oct 1995)

In July 1995 an Air Force member of the Joint Stars aircraft development and testing team funded AFRL to participate in ground IR signature measurements of the Joint Stars aircraft at Eglin AFB. Simultaneous measurements and testing were being accomplished with IR countermeasures for the C-17 aircraft. To support this measurement, SRL modified their mobile laboratory to support 4 half-size racks of equipment. Power, cabling, intercom, and support equipment were added to the mobile laboratory. An instrumentation mount supporting numerous AFRL sensors on a single tripod was developed and tested. Figure 1 shows the modified mobile laboratory at the ground site at Eglin AFB, on the C-52 ground test site. Figure 2 shows the instrumentation mount developed for these tests. This equipment was packed in the mobile laboratory and trucked down to Eglin AFB at the beginning of September 1995.

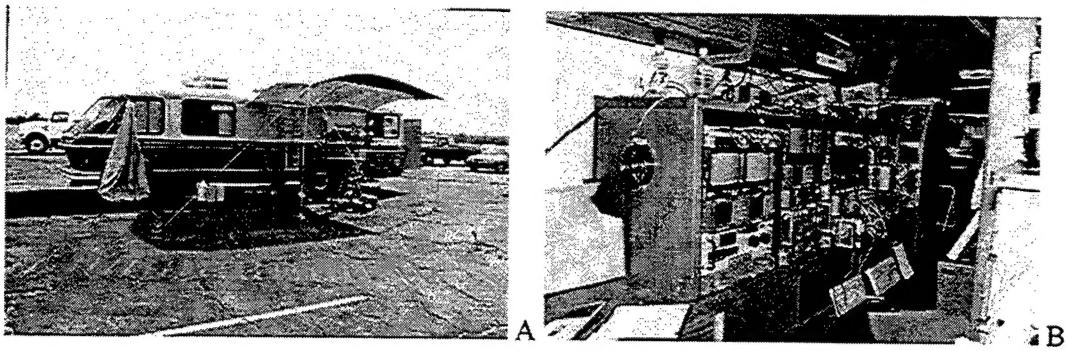


Figure 1 SRL Mobile Laboratory Deployed to Eglin AFB Ground Site for Joint Stars Measurements, (A) Mobile Lab on Site, and (B) Lab Interior

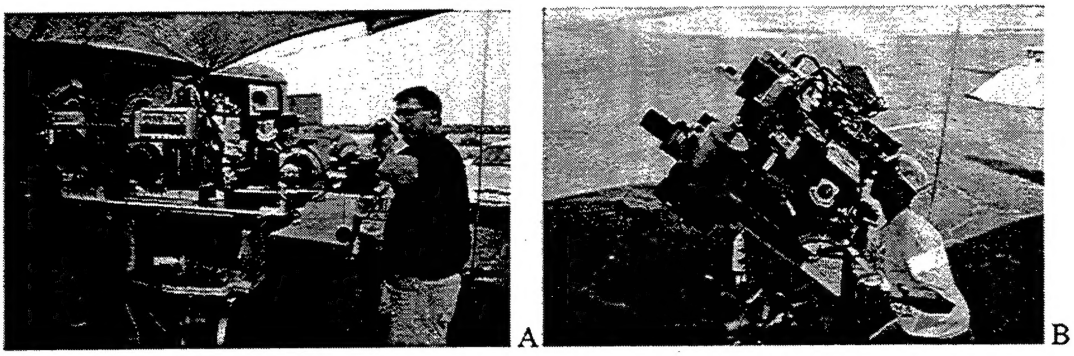


Figure 2 Sensor Mount Developed for Ground Measurements, (A) Instrument Configuration on Mount, and (B) Tracker Following a Target with Mount

Two sets of ground measurements were accomplished. The first set was accomplished in mid-September 1995. Ground measurements of the C-17, the Joint Stars, and some infrared countermeasures were made. About a 1 month delay was required in the testing program, so the equipment was left at Eglin AFB and the AFRL and SRL personnel returned home. The advent of Hurricane Opal in early October 1995 forced two SRL personnel to rapidly deploy to Eglin just ahead of the hurricane and evacuate all the equipment to Atlanta, GA. The equipment was stored there until late October 1995, at which time AFRL and SRL personnel returned to Atlanta and drove the equipment back down to Eglin AFB, re-setting up the ground measurement site. Additional data on the Joint Stars and C-17 aircraft was collected during this second deployment. Figure 3 shows the Joint Stars aircraft flying over the ground site, and dispensing some flares. After the data collection was complete, the equipment was packed up and re-shipped in the mobile laboratory back to Bedford, MA.

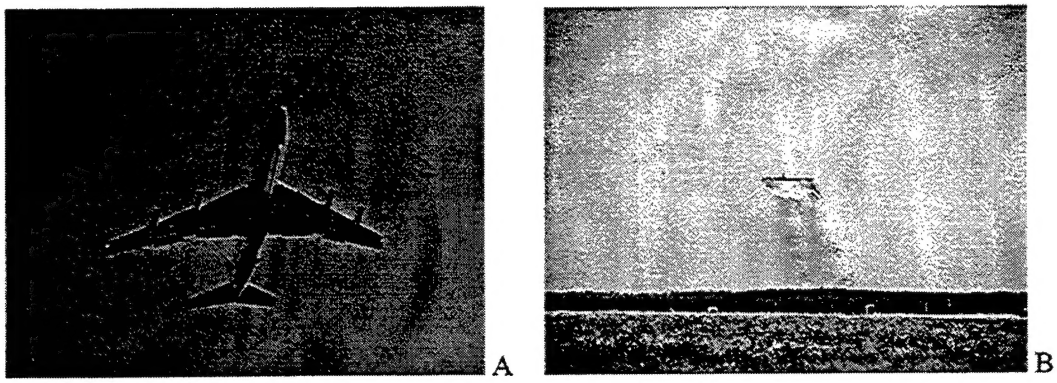


Figure 3 Ground Measurements During October 1995, (A) Joint Stars Aircraft Overflies the Ground Site, and (B) Flare Dispensing During Data Pass

2.3 AC-130 Gunships (February 1996)

SRL supported ground measurements of AC-130 gunships at the end of February 1996 at Hurlbert Field, FL. The sponsor of this effort was the 18 FLTS of the Air Force Special Operations Command (AFSOC). A trailer was acquired by AFRL, and this trailer was modified to accept equipment racks and support equipment to allow operation of the FISTA sensors. A second instrument mount, to allow use of additional sensors, was designed and built. FISTA equipment was loaded into the trailer and trucked to Hurlburt Field. A measurement deck was

designed and built off the back end of the trailer. Photographs of the trailer and the measurement deck, with instrument tracking mounts, are shown in Figure 4.

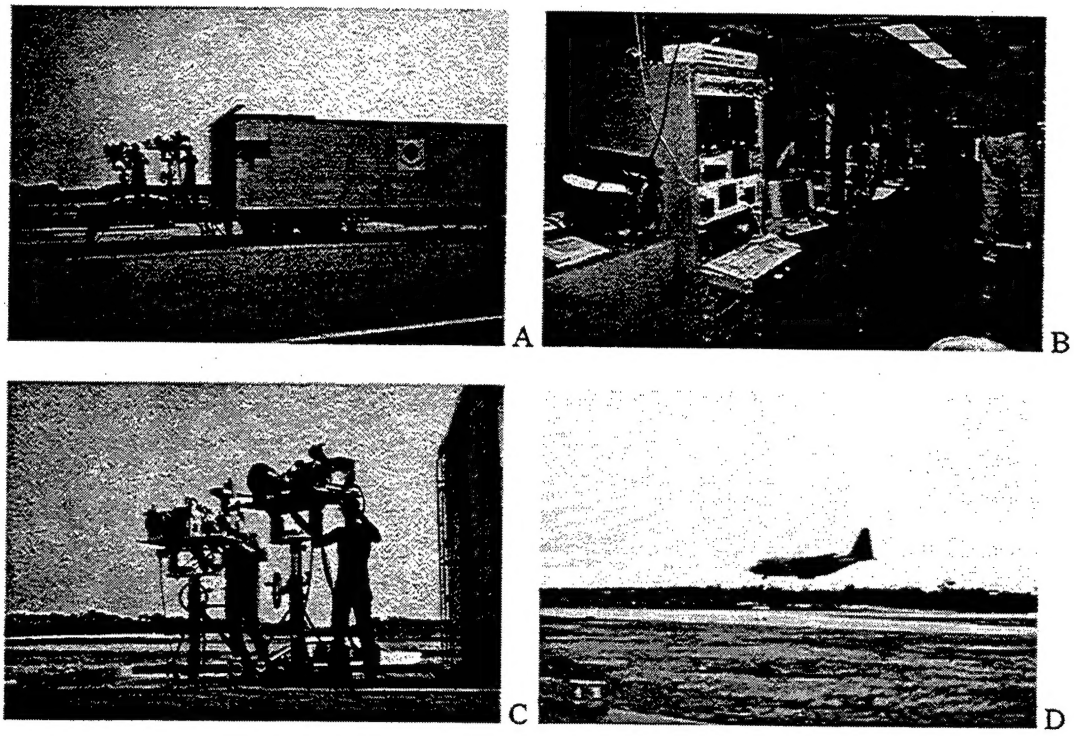


Figure 4 February 1996 Ground Measurements of AC-130 Gunships, (A) AFRL Trailer and Instrument Deck, (B) Trailer Interior with Equipment, (C) Both Instrument Tracking Mounts, and (D) Aircraft Test Pass

Measurements were collected of AC-130H and AC-130U gunships flying a variety of profiles and engine settings. Data were also collected on AC-130H aircraft without IR suppressors. A limited set of data on a UH-60 helicopter was also collected. Almost all of the data were collected at night.

2.4 Gunship IR Suppressors (December 1996)

SRL supported ground measurements of the Mark 1 infrared suppressor installed on an AFSOC AC-130H and AC-130U aircraft at Hurlburt Field, FL in December 1996. A complete suite of instrumentation was transported to Florida on the AFRL trailer, and a series of flight tests measured the performance of the suppressor, as well as other IR suppressors and unsuppressed aircraft. These measurements were jointly conducted with sensors from Georgia Tech Research Institute (GTRI) and were part of the evaluation of the performance of a single Mark 1 suppressor.

The 46 TW at Eglin AFB also participated in these measurements with an infrared imaging interferometer (IRIS) system. SRL supported modifications to the sensor mounts to allow the IRIS system to be tracked with the other ground sensors. The IRIS computer and cabling was temporarily installed in the AFRL trailer for the duration of these measurements. One of the AFRL Amber cameras was coaligned and the field of view location of each interferometer pixel was mapped, to allow inband IR images to be coupled with the imaging interferometer results. Covers were designed and built for the instruments to isolate them from adverse weather and

improve radiometric calibration. Despite temperatures near freezing, a good data set was collected and the evaluation of the Mark 1 performance was completed in February 1997.

2.5 Polarized Targets and Backgrounds (July 1997)

In July 1997 AFRL deployed a flight crew and instrumentation to Edwards AFB to conduct several background measurement flights for the RAMOS (Russian Amerian Observational Satellite) program. SRL provided three flight crew and pre-flight calibration and configuration support. SRL accomplished extensive modifications to several AFRL instruments to allow measurement of IR polarization with both spectrometers and magers. The hardware changes are shown in Figure 5. A polarizer rotator was developed that used a Geneva mechanism to rapidly rotate the polarizer by 60 degrees and then hold it in place while the measurement data was collected. A separate control chassis was developed to control 3 independent polarizer units. The polarizer electronics were interfaced into the circuitry of interferometer 102 so that the polarizer advanced during the interferometer retrace. Polarizer and attenuator readouts were added to the circuitry in the polarizer controller, and new Windows-based data interferometer collection software was developed to interface to the polarizer data and record all required information. Software changes were made to the spectrometer software to support polarizer processing, including spectral calculations of the solution of the Stokes vector results from interferometer measurements. Another polarizer was interfaced to the SAIRS camera, and the position readout was inserted into the video for post-data processing. A third polarizer rotator was designed and built for the cryogenic radiometer, and new data recording software was developed to use the newly built control console and record the polarizer positions. The polarizer units and instrument modifications were ground tested at AFRL prior to deployment to Edwards AFB.

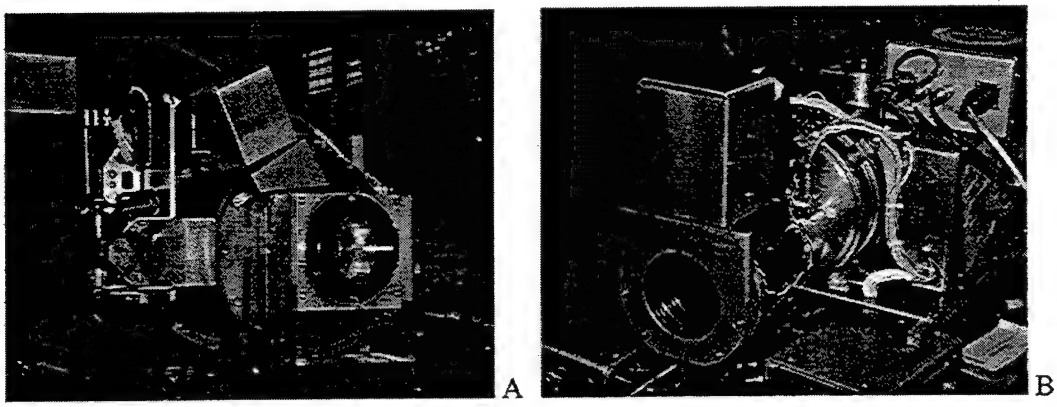


Figure 5 Infrared Polarizer Modifications Made to FISTA Sensors for July 1997 Measurements, (A) Polarizer Front End on Cryogenic Radiometer, (B) Polarizer Installed on SAIRS Imager

Three flights were accomplished in July 1997, and a large data set was collected for initial analysis by the RAMOS program. This was the first full equipment deployment to Edwards AFB, so considerable logistical details had to be sorted out and procedures established for future deployments. A small amount of polarized target data was also collected on targets of opportunity during in-flight refueling support by the FISTA aircraft.

2.6 F-16C IR Signatures (September 1997)

In September 1997, AFRL, supported by SRL, deployed to Edwards AFB for inflight measurements. The first half of the deployment consisted of additional measurements of polarized solar scatter off clouds, and long downlook tracks, for the RAMOS program. Lessons learned from the July 1997 flights were applied on these flights. A second interferometer (S/N 105) was modified to accept a polarizer, with a fourth polarizer controller fabricated and data collection software modifications. These were also the first flights of the PEELS (Portable Eyesafe Lidar System) lidar system (developed by Visidyne Inc), to provide accurate range to the clouds. On the second half of this deployment, inflight measurements of a New Mexico Air National Guard Block 40 F-16C were made. These target measurements were funded by AFOTEC (Air Force Operational Test and Evaluation Center), to provide infrared signature data for testing and validation of the GTSIMS (Georgia Tech Simulations Integrated Modeling System) F-16C module under development by GTRI. The existing F-16C signature database was judged insufficient by GTRI because the flight conditions in that database did not match the flight conditions for which the new GTSIMS model was developed. The FISTA aircraft conducted measurements over a series of low altitude, high speed profiles using the test ranges near Edwards AFB. SRL provided 4 crewmembers for this deployment, as well as test plan development support, pre-flight instrument calibration and configuration work, and assistance in aircraft installation and equipment deployment to and from Edwards AFB.

2.7 Laboratory Comparisons with NAWC (March 1998)

In March 1998, SRL supported the deployment of selected FISTA instrumentation to a joint calibration measurement with the ATIMS (Airborne Turret Infrared Measurement System) group from the NAWC (Naval Air Warfare Center) at Arnold Engineering Development Center (AEDC) in Tullahoma, TN. The goal of these measurements was to provide comparisons of simultaneous measurements of laboratory sources with the NAWC and AFRL sensors. The AFRL trailer was used to transport all equipment to AEDC for these tests. A series of joint measurements of a variety of low and high temperature sources was jointly made. The window calibrators for the FISTA aircraft (both hot and cold) were also brought along and observed as calibration standards with sensors from both groups. The surface emissivity of the Ebanol C treatment of the calibrator copper plates was measured using facilities at AEDC. A monochromator source was used to collect spectral characterization of the Agema and SAIRS sensors, in each filter band. Extensive discussions on calibration methods and standards also occurred between the FISTA and ATIMS measurement groups.

Three SRL personnel traveled to AEDC and spent a week supporting the joint measurements. Figure 6 shows part of the laboratory calibration setup, including both data collection and data reduction systems.

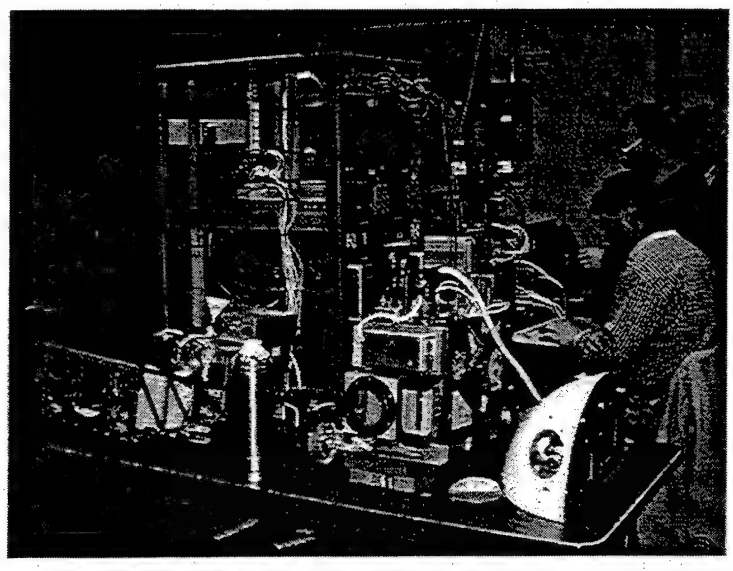


Figure 6 AFRL Sensors In Use During Joint FISTA-ATIMS Measurements at AEDC in March 1993.

2.8 F-15 IR Topcoat Tests (May 1998)

AFRL and NAWC conducted joint flight measurements of an F-15E partially painted with a moderately reflective topcoat paint. The goals of these measurements were to demonstrate that AFRL and NAWC calibrated data agree when simultaneous measurements are made, and also to evaluate flight times and test point timing for the supersonic points to be flown by ATIMS in the eventual F-22 flight tests. Three flights with all three aircraft were made (missions 9810, 9811, and 9812). The window calibrators were operated during these flights to provide an external calibration source for the ATIMS sensors. The HIP (Hyperspectral Imaging Polarimeter) instrument aircraft installation and modification was also completed prior to these flights, and the HIP sensor was operated exclusively in a testing mode during these flights, collecting background data only. Figure 7 shows the target aircraft and the ATIMS aircraft during these tests.

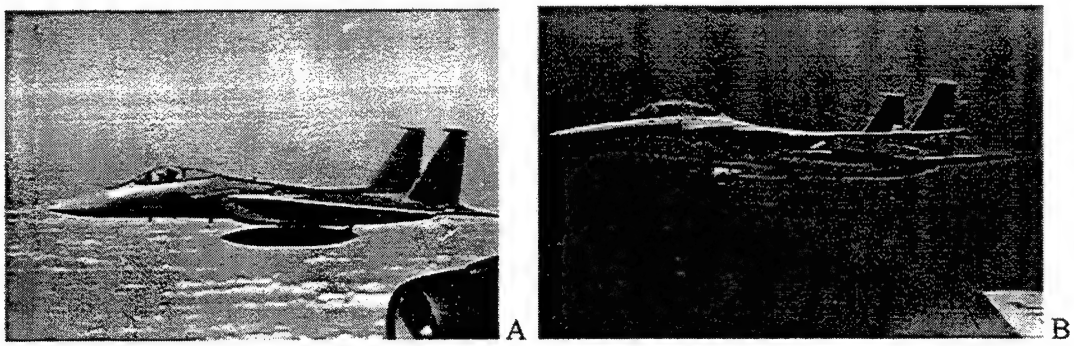
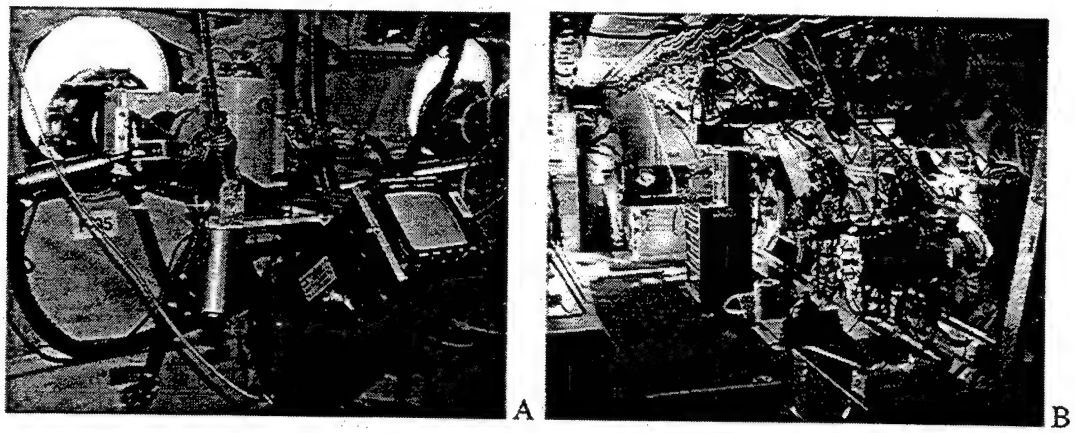


Figure 7 Aircraft During IR Topcoat Test in May 1998, (A) Target Aircraft, and (B) ATIMS Aircraft with Pod

2.9 Polarization Background Measurements (September/October 1998)

In September and October 1998, AFRL again deployed to Edwards AFB to collect data in support of the Ballistic Missile Defense Organization (BMDO) RAMOS program. New sensors

used during this deployment were the 3D Lidar and the Russian Aquameter. SRL modified the Amber 256x256 imager to accept an IR polarizer, and modified the digital data recording system to record polarization information and to sync with the polarizer position. Figure 8 shows the modified Amber system, with polarizer, installed on the FISTA aircraft, and one of the instrument configurations used during these flights.



A B

Figure 8 Infrared Sensors Installed on FISTA Aircraft for September/October 1998 Flights, (A) Amber System with Polarizer, and (B) Instruments Installed for Side Look Flights

Downlook and sidelook data were collected over a series of 6 flights (missions 9825, 9826, 9827, 9901, 9902, and 9903). SRL provided 3 crewmembers and extensive support while in the field. Part of this effort was funded separately under the SDL RAMOS contract with BMDO.

3 Data Reduction and Analysis (SOW 1.1 and 1.2)

The data reduction and analysis effort under this contract focused on 10 major data sets. Work on each of these is summarized in the following sections. Since most of the data are sensitive or classified, data examples from each effort are not included here.

3.1 C-17A Data Set

Extensive data reduction and analysis was accomplished on the data set collected by FISTA in August 1993. Both spectral and spatial data were selected, reduced, and calibrated in support of the SPIRITS (Spectral and Inband Radiometric Imaging of Targets and Scenes) target module development. A calibrated database was assembled and delivered to Spectral Sciences, Inc, in support of their SPIRITS module development for the C-17A, in May 1994. Data reduction for the C-17A measurements was essentially completed in Aug 94. Some work occurred in the second half of 1994 on the associated databases that contain target and measurement parameters from the two flights. Data analysis of the C-17A measurements continued in support of SPIRITS model development through December 1994.

3.2 B-2 Data Set

The FISTA aircraft made a second set of infrared signature measurements of the B-2 in March 1993. Extensive data reduction and analysis of this flight data set occurred between July and September 1994. A large database was reduced and calibrated. Eventually three additional datapacks, each with a supporting report, were developed and delivered to Northrup-Grumman prior to June 1995. SRL personnel also participated in a B-2 data and modeling review at the Northrup-Grumman plant in Pico Rivera, CA, in June 1995.

3.3 Tactical Missiles Data Set

The FISTA aircraft collected a limited set of infrared signature measurements of tactical air to air missiles launched from F-15 aircraft in June and September 1993. Analysis of these data were accomplished from January to July 1994, and a report on the results was delivered to the JTAMS (Joint Tactical Missile Signatures) office (program sponsor) in August 1994. Around the same time AFRL and SRL personnel traveled to the JTAMS office in San Antonio, TX to discuss databasing issues and transfer formats for the delivery of the tactical missile data into Air Force databases.

3.4 F-117A Data Set

In July 1993 FISTA made inflight measurements of the F-117A aircraft. Part of these measurements were an investigation of the properties of research oriented surface coatings. The measurements also addressed some issues concerning the basic signature of the F-117A aircraft. Funding from the F-117A SPO (Program Office) was received in July 1994 to begin work on this data set and to develop a SPIRITS module based on the flight data. Data reduction and analysis of this data set occurred between July 1994 and May 1995. An inflight database was developed, and a SPIRITS module was made with it. The module and report were delivered to the F-117A SPO in June 1995. SRL also participated in an F-117A data review meeting at the end of May at the Lockheed Martin plant in Palmdale, CA.

3.5 Joint Stars (E-8C) and C-17 Ground Data Set

Data reduction and analysis was done on the ground-based data measurement set collected at Eglin AFB in September and October 1995 on the Joint Stars (E-8C) and the C-17 aircraft. Selected data segments, including both targets and countermeasures, were reduced and calibrated. A small selection of engine data from the C-141 flight signature measurements in August 1993 was also reduced, to allow limited comparisons between those engines and the Joint Stars engines. These limited comparisons were discussed with the Joint Stars measurement sponsor. This work occurred between October 1995 and April 1996.

3.6 C-141 and C-5A Data Sets

A limited effort of data reduction and database development was completed on the C-141 and C-5A FISTA flight data sets from August 1993. This occurred between January and July 1996.

3.7 AC-130H and AC-130U Ground Data Sets

Extensive data reduction and analysis was done on the ground data collected during the Hurlburt ground measurements in February 1996. This work took place between March and December 1996. The data results were used to assist the AC-130H SPIRITS module development occurring during this time frame at Spectral Sciences, Inc. Ratios between the suppressed and unsuppressed signatures were measured from the data, and data were assembled to allow a detailed assessment of the operation of the existing gunship IR suppressors. Results of this work were orally presented to AFSOC representatives in October 1996 and January 1997. The data also supported several SPIRITS modeling efforts in this area.

3.8 Mark-1 IR Suppressor Data Set

The data set that was collected on the prototype Mark-1 IR suppressor for the AC-130 gunships in December 1996 was assessed and parts were analyzed. A quicklook evaluation of the performance of this suppressor, along with comparisons of existing suppressors and unsuppressed aircraft, was prepared and presented to AFSOC representatives. The results of this assessment precluded any additional work on the Mark-1 data set. SRL personnel also presented a paper on the performance of the C-130H IR suppressors at the IRIS Targets, Backgrounds, and Discrimination meeting in Monterey, CA in January 1997.

3.9 F-16C Data Set (AFOTEC)

SRL conducted an extensive data reduction and analysis effort on the F-16C data set collected in support of AFOTEC modeling evaluation in September 1997. This included spectral and spatial data reduction and calibration, with SRL funding some range and aspect angle determination from the tracking videos. An extensive set of data was compiled from two of the flights. Data reduction and the databasing effort using Foxpro continued through April 1998. At that time, SRL delivered a set of 2 CDROMS with a full set of data and databases to GTRI and the sponsor (AFOTEC). In an August 1998 technical meeting at GTRI in Atlanta, the CDROMs and their contents were reviewed. This data supported model development and validation of the performance of the GTSIMS F-16C target module.

3.10 Topcoat Flight Data Set

Data from the Topcoat flight tests in May 1998 were analyzed from June through December 1998. An extensive database was developed for comparisons to the NAWC in-flight measurements with the ATIMS pod. Several meetings and data exchanges were held with NAWC representatives to discuss the data and compare the results. A CDROM set of data was organized and delivered to NAWC in October 1998 with the full set of calibrated data results and support databasing. Work on this data set has continued under the new follow-on FISTA contract.

3.11 RAMOS Data Set

Extensive data sets titled "FISTA97" and "FISTA98" of the RAMOS flight measurements were developed in 1997 and 1998. Virtually all of this work was funded through the BMDO task-order contract with Space Dynamics Laboratory, and thus it is not discussed as a product of this contract.

4 Databasing Support (SOW 1.2)

SRL provided extensive database development support with the reduced and calibrated data from the FISTA aircraft. This database effort was an attempt to get the large FISTA data sets into a system and format that is generally accessible to other users. This is quite a formidable task, as the support data must be gathered and put into a form where it is all time-tagged and electronically accessible through database software. This effort originally was sponsored by the Air Force Information Warfare Command (AFIWC), Kelly AFB, TX. A significant effort was expended both in developing the database tools and framework for this effort, as well as getting several specific datasets prepared and installed into it. A standalone FISTA database, which contained only conditions and filenames (no actual data) was also developed in this effort. The tools and experience gained in this effort were used in the development of specific databases delivered to end users, such as the F-16C data set, the Topcoat test data set, and the extensive RAMOS data sets collected in 1997 and 1998.

4.1 C-130H Database

An extensive set of C-130H flight data was reformatted to the AIMG (Airborne Infrared Measurement Guide) specification from AFIWC and delivered to AFIWC in August 1994. SRL also participated in extensive technical exchanges with AFIWC concerning database issues and methods of preparing and delivering FISTA data to large databases. SRL attended several meetings at AFIWC in Kelly AFB, San Antonio TX as part of this effort.

4.2 B-1B Database

Work was accomplished on gathering old B-1A and newer B-1B flight data into a single measurement database. Engine parameters and support data for these data sets were moved into electronic format. This effort occurred in October 1994 to March 1995.

4.3 KC-135R Database

The KC-135R flight measurement database from 1990 was reformatted and databased. A data pack of KC0135R signature data was also delivered to Spectral Sciences Inc in support of their modeling updates on the SPIRITS KC-135R target module.

4.4 Rocket and Plume Database

Work was accomplished towards moving the full set of rocket and missile infrared signature data collected over the years by FISTA to the Advanced Missile Signature Center (AMSC) databases. A list of databases and reports was identified with AMSC representatives, with work to occur as funding became available. Sufficient funding was received to scan a portion of the documents, convert some to PDF format, and also to gather and convert some of the rocket databases to electronic format.

4.5 F-16C Database

The large set of F-16C data collected by FISTA in September 1997 was converted into a database of 2 CDROMS that were delivered to GTRI and AFOTEC in April 1998 and to AFIWC in May 1998.

5 SPIRITS Model Testing/Work (SOW 1.3)

SRL was funded to support SPIRITS target module development and testing, and became involved in AFRL work on several target modules. This work is summarized briefly in this chapter.

5.1 C-130H Target Module

SRL played an important role in the development, validation, and documentation of the initial C-130H SPIRITS target module. This work started in January 1994. SRL delivered a complete SPIRITS module of the C-130H, with a preliminary draft report, to AFIWC in Kelly AFB, TX in April 1994. The draft report contained complete documentation on the module, as well as the results of test cases, matrix cases, and module algorithms. This module was used extensively by AFIWC to support modeling and system studies with IR tactics and countermeasures for the C-130H. Upgrades of the module and documentation were accomplished from June to December 1998.

5.2 C-17A Target Module

SRL supported testing and initial validation of the beta C-17A SPIRITS module, which was delivered to AFIWC in mid-June 1994. Some special C-17A data analysis and modeling was completed in support of a hardware-in-the-loop test for AMC (Air Mobility Command), as part of the support task for operational commands (SOW 1.5). The model testing and data results were delivered to AFEWES in March 95. SRL personnel traveled to Fort Worth, TX, around this time to present the C-17A modeling results. A draft report on the work was completed, and 1 copy delivered. The report was subsequently published by AFRL.

5.3 B-52H Target Module

SRL participated in the development and independent testing of the SPIRITS B-52H target module, which started in September 1994 and was completed approximately in June 1996. This effort used existing FISTA flight data from 1982 to develop the module. SRL selected some of the 1982 data and reduced it for module development and independent validation testing. SRL also participated in all of the technical interchange meetings to discuss model development. Once the module was completed, SRL conducted an independent analysis of it using additional flight data not available to the model developers. A chapter describing this independent evaluation was contributed to the SPIRITS module documentation.

5.4 ALCM Target Module

SRL assisted in the validation and testing of the SPIRITS ALCM (Air Launched Cruise Missile) module between October 1994 and December 1996. This consisted of attending several technical interchange meetings, running the code independently, and reviewing some of the very limited flight signature data available on this target.

5.5 F-117A Target Module

SRL developed and delivered a SPIRITS AC1 target module for the F-117A. The primary source of flight data was collected by FISTA in July 1993. The data was analyzed and a valid model, for those flight conditions, was developed and delivered to the F-117 SPO and Lockheed-Martin Skunk Works in Palmdale CA in June 1995. Results of this model, and comparisons with

the existing Lockheed modeling, were also presented at meetings around this time. A report describing the target module was written and delivered to the SPO.

5.6 F-15E Target Module

SRL did some testing of the SPIRITS F-15E module in June 1996 and wrote a short study with a matrix of F-15E signature predictions for the 57th Test Squadron at Nellis AFB in July 1996.

5.7 F-22 SPIRITS Modeling

SRL participated in the F-22 SPIRITS modeling effort from May 1995 through the close of the contract (the effort is still ongoing). SRL attended numerous flight test working group meetings, where the upcoming infrared specification compliance flight tests were planned and discussed. SRL drafted the initial test point matrix to support the model validation effort. Numerous modeling efforts were presented at these meetings. SRL was part of the acceptance and initial testing of the SPIRITS-GSL-3 version prepared to address F-22 concerns. Technical presentations at Aerodyne Inc and Wright Patterson AFB were attended, and the code was received and run at AFRL with initial test assessment cases. The GSL Graphical User Interface was also tested at AFRL. SRL participated in the modifications and testing of the initial F-22 wireframes, creating first an extensive log of the wireframe contents, and then reworking the configuration to better match SPIRITS model requirements. SRL was part of the information exchange with the F-22 SPO and Lockheed technical personnel on the performance and use of the F-22 thrust cycle deck in March 1997. The aircraft instrumentation configuration was confirmed for the F-22 flight tests in a series of teleconferences. Extensive information on paint materials and optical properties was also exchanged in this effort. SRL attended meetings with the F-119 engine SPO and manufacturer (Pratt-Whitney) during this effort, collecting data and monitoring tests that yielded data of value to the eventual modeling effort.

6 GTSIG Model/Testing (SOW 1.3)

SRL supported an effort by Air Force Operational Test and Evaluation Center (AFOTEC) at Kirtland AFB to develop an F-16 target module for the GTSIMS engagement model that would eventually be used in Common Missile Warning System (CMWS) testing. The AFRL and SRL role in this program was to provide independent modeling support and an assessment of the work by Georgia Technical Research Institute (GTRI). In this role, SRL supported initial delivery of the existing SPIRITS F-16 model to GTRI and also created a database out of existing FISTA F-16C measurements (from 1988). Numerous planning and progress meetings were attended during model development. GTSIMS was received and installed on the AFRL workstations. A complete first version of the GTSIMS module was received (without documentation) in October 1997 from GTRI. The module was reverse-engineered enough so that test runs could be set up and executed. A series of GTSIG/GTRENDER calculations were completed and compared both to similar SPIRITS model calculations and to flight data. The results of this comparison were presented in February 1998 at AFOTEC. This comparison forced extensive rework of several components of the target module. The revised model was reviewed in a technical meeting at GTRI in Atlanta, GA in August 1998. Final versions of the code, and draft documentation, were received in October 1998 and underwent some testing and evaluation at AFRL. Completion of the model V&V effort has extended into the follow-on contract awarded to SRL.

7 Hardware/Instrument Development (SOW 1.4)

SRL accomplished an extensive list of hardware modifications and new hardware development under this contract. Each of these efforts is summarized in this chapter.

7.1 FISTA II Upgrade

The FISTA II upgrade consisted of modifying aircraft S/N 55-3135 to accept all of the AFRL sensor systems from the retired aircraft S/N 55-3120. This involved Class II aircraft modifications to accept instrument eyeball mounts, equipment racks, extensive cabling, and power system modifications. The task was supervised by the aircraft modification shop at Wright Patterson AFB, OH. The bulk of the design and equipment preparation was accomplished by AFRL and two subcontractors, Visidyne Inc, and SRL. The modification started in January 1994 and was finished with the successful test flight of FISTA II in May 1995. SRL contributed extensive design and drafting support to the modification, and also participated in design review meetings and the preparation of the Class II modification package paperwork. SRL also supported the eventual installation of the hardware on the aircraft and provided 4 crew in the acceptance test flight in May 1995.

7.2 Cryogenic Radiometer Upgrade

The control console for the cryogenic radiometer was rebuilt during the period June 1995 to April 1996. The control console was redesigned to accept two commercial lock-in amplifiers set for the radiometer chopper frequency. This eliminated need for the large Princeton Applied Research lock-in amplifier chassis. The instrument head was modified to provide readouts of the filter position and several temperatures. The console provided filter position, gain settings, and time constant in computer readable versions. The revised front panel provides both the raw radiometer signals as well as the DC rectified signal from the lock-in amplifiers. Panel meters were added to allow easy monitoring of these signals. This console was interfaced to the portable computer data collection system (developed under the RAMOS effort) to allow recording of this new information and to enhance post-processing of the data. A photograph of the modified console front is shown in Figure 9.

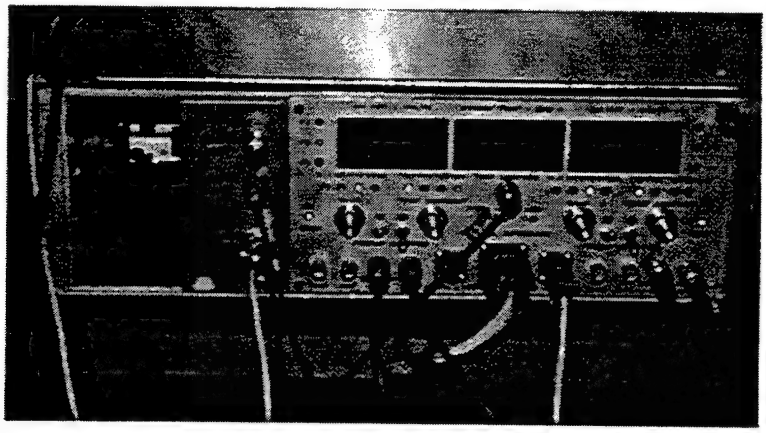


Figure 9 Upgraded Radiometer Console

7.3 Interferometer A/D Upgrade

A series of upgrades to the AFRL interferometer S/N 105 were made during the time period July 1995 to June 1996. The servo electronics for the two interferometer speeds were modified to allow easy switching between the two scanning speeds. A switch was added on the interferometer to enable this change. Separate detector pre-amplifiers, each optimized for the frequency band of the nominal speed, were added to the head. Some of the digital timing and control logic were redesigned and rebuilt in the head, both to provide cleaner signals for the computer interface and to enhance operation. Power wiring was changed to reduce cross-talk and minimize ground loop problems. An attempt was made to add an A/D (analog to digital converter) to the head to provide digital output signals. White light position and total point count were inserted into the data stream after each interferogram. Several iterations of designs and tests were completed but none of these prototypes proved satisfactory. The improvement is continuing in the current SRL FISTA contract.

7.4 SAIRS Digital Recorder Interface

AFRL procured two Ampex DIS-120 high speed digital recorders in 1995. SRL designed and built an interface between the SAIRS camera and these recorders. This task occurred between August 1995 and May 1996, with some testing effort continuing after that. At that time, most of the imaging IR sensor data was recorded in video format, since this is a low cost and easy to use medium for storing the enormous quantity of data collected by an imager. The disadvantage of video is its relatively low dynamic range (about 40 dB) and the need to manually select and digitize frames from the video during post processing. In past years the extremely high cost of digital recorders capable of keeping up with video data rates precluded their use on the FISTA aircraft. In 1995 digital recording prices began to drop sharply, and AFRL invested in the technology and started using it for field data collection. AFRL purchased two DIS-120 recorders from the Ampex Corporation. This interface eventually allowed the digital image data of the SAIRS to be directly recorded in digital format.

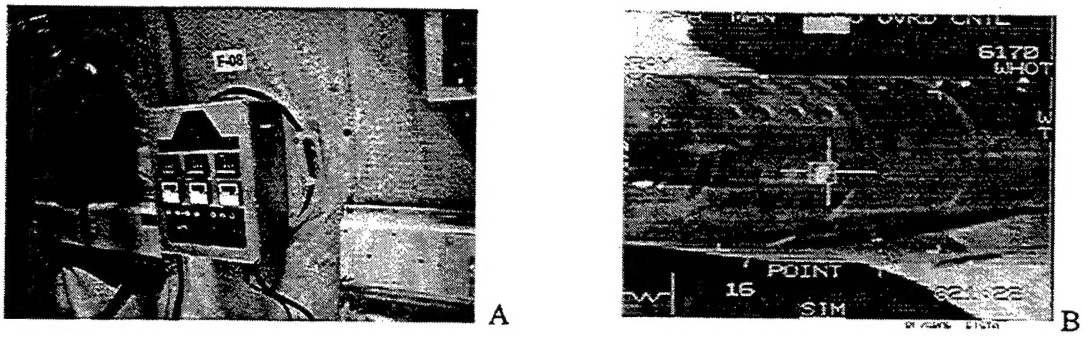
The difficult part of this interface was accessing all of the instrument housekeeping data and inserting it into the data stream for each frame. Substantial modifications to the SAIRS instrument console were needed to provide access to this data. The SAIRS head was modified to provide a separate high-speed A/D for this system. A complete console was built up with all the electronics to buffer SAIRS digital data and insert the header information at the start of each frame of data. The system was demonstrated at AFRL in May 1996. Some problems with dropped bytes and intermittent data operation were noted. The system was adjusted and these problems were reduced. The tape drives have not yet been installed on the FISTA aircraft for routine digital recording use.

7.5 AFRL Trailer and Ground Measurement Equipment

SRL supported the initial buildup (January to February 1996) of the AFRL trailer to support ground measurements and equipment transportation to and from Edwards AFB. The trailer was modified to accept equipment racks used on the aircraft, and numerous wiring modifications were made. In preparation for subsequent ground deployments, SRL also supported design and fabrication of the instrument measuring platform, including cables and mounts specifically designed for ground measurement applications.

7.6 Airborne Calibration Sources

SRL designed and built two airborne calibration sources for use on the FISTA aircraft by the ATIMS II pod instrumentation. These calibrators provided an inflight radiometric source for the pod instrumentation to be used for Topcoat and eventually F-22 signature flights. The sources mounted in FISTA windows and were viewed by the ATIMS instruments when the host F-15 flew in formation with the FISTA aircraft. Extended hot (140 C) and cold (liquid nitrogen) sources of approximately 12 inch diameter were made. A preliminary design of these were made in January 1997. The main mechanical design and fabrication work took place between January and July 1997. In April 1997 the drawing and documentation package for Class II modification installation on the FISTA aircraft was started. SRL developed a complete modification description package, including stress analysis of each calibrator. These packages were presented to the Edwards modification center in July and September 1997. The calibrators were formally added to the FISTA suite as approved aircraft modifications in September 1997. At that time the sources were flown in the background during other flight tests. Figure 10A shows the hot source installed on the FISTA aircraft, while Figure 10B shows an infrared image from a sensor on the F-16C flying with FISTA in September 1997 that illustrates operation of the hot calibration source.



A B

Figure 10 FISTA Window Calibration Sources, (A) Hot Extended Source Installed on FISTA Aircraft, and (B) Infrared Image Showing Operation of Hot Source During Test Flight in September 1997.

These sources were operated during the Topcoat flights in May 1998 and used by the ATIMS pod as external calibration sources.

7.7 AFTIS Interferometer Upgrades

SRL made significant upgrades and repairs to the ATIMS III AFTIS (Airborne Fourier Infrared Spectrometer) interferometer during the period November 1996 to December 1997. Initially the AFTIS interferometer was a non-functioning system that was not satisfactory to the ATIMS group at Pt. Mugu NAS, CA. A data collection system was developed and installed at SRL, and the SPL software was modified to accept and work with data from this interferometer. Laboratory calibrations and assessments of system sensitivity were made and delivered to NAWC. A number of ground loops and other electronics problems in the instrument head were fixed. A former employee of Block Engineering, familiar with the instrument, was hired on a consultant basis and extensive checks of the digital electronics were made.

Based on this testing and the requirements of pod operation, SRL designed and installed two hardware modifications in the AFTIS sensor head. One modification provided monitoring of the

interferometer white light signal and added it to the data stream. The other modification replaced the cube temperature control with a more sophisticated controller and added several temperature points for monitoring. The cube temperature data was reformatted and provided as an RS-232 data stream that could be recorded on the data recording computer. Figure 11 shows the AFTIS interferometer set up in the laboratory at SRL for testing and evaluation.

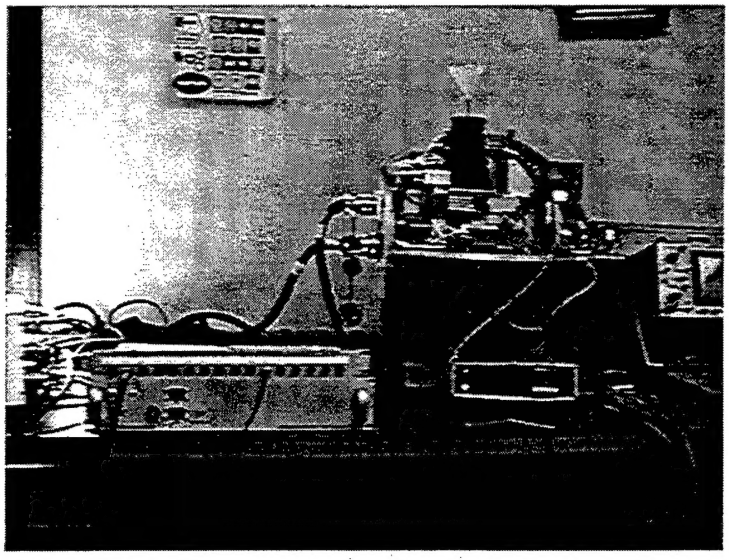


Figure 11 AFTIS Interferometer In Laboratory Tests at SRL

In October 1997 the instrument was operated at SRL through a complete set of radiometric calibrations. Simultaneous measurements of the calibration sources with an AFRL interferometer were made (S/N 105) for data comparison. Samples of this data were reduced and analyzed. The AFTIS instrument was then returned to Pt. Mugu NAS in early December 1997. Two SRL personnel traveled to NAWC and demonstrated operation of the modified instrument hardware and software on site.

7.8 Hyperspectral Imaging Polarimeter Installation

SRL assisted in the aircraft modification and installation of the Hyperspectral Imaging Polarimeter (HIP) between January and May 1997. SRL assisted in development of the aircraft modification package and reviewed drawings and cable design. SRL also helped build up part of the equipment rack at AFRL. It was then shipped to Space Dynamics Laboratory in Logan, Utah for completion and operational testing.

7.9 Equipment Modifications for Engine Static Tests

SRL developed several equipment modifications to support infrared measurements of static aircraft engine runs while installed on a test stand. Long cables for an interferometer and an imager were developed and tested in the laboratory. Two mounts for large mirrors, to be placed in the aircraft engine exhaust, were designed and built. One large inexpensive front surface mirror was procured and tested for suitable infrared reflectivity. An automated calibration source controller was also designed and built, to allow remote insertion of extended calibration sources in front of AFRL instrumentation. An automated aperture wheel and background correction plate were designed, built, and tested for one of the SAIRS lenses.

8 Subcontracts

SRL issued one subcontract under this contract, with Photometrics Inc of Woburn MA. This subcontract was used to obtain target ranging and data analysis support between June and October 1996. Under this effort Photometrics also completed data collection and calibration tools needed for working with video data collected by the MAVIS visible imaging system.

9 Publications

SRL contributed to 12 classified technical reports under this contract.